5.0 Weight, Length and Condition by Species and Reach

This chapter discussed the derivation and interpretation of condition factors.
Fish weight, length and "condition" were compared statistically by Reach and with total mercury. In yellow perch condition was significantly negatively correlated with total mercury.

5.1 Condition Factors

As Carlander (1977: 9-10) notes:

"Since the weight of a fish varies with the cube of its length, provided the shape and specific gravity remain the same, any change in the shape or relative plumpness of a fish will cause a change in the value of *c* in the formula:

(1) $W = cL^3$

"Fishery biologists have used this fact in describing the condition, plumpness, or well-being of a fish. The coefficient of condition, K, or Fulton's condition factor has been widely used:

(2) $$K = \frac{W x 10^5}{L^3}$$

where,

W = weight in grams
L = length in millimeters
and 10^5 is a factor to bring the value of K near unity.

The method of length is indicated as K-SL, K-FL, or K-TL."

SL = standard length
FL = fork length
TL = total length

In the current study condition factors are calculated as K-TL.

Dethloff and Schmitt (2000:13) note,

"The condition factor is an organism-level response, with factors such as nutritional status, pathogen effects, and toxic chemical exposure causing greater-than-normal and less-than-normal weights.....Both the condition factor and organo-somatic indices[50] are used as indicators of the well-being of individual organisms."

Because it integrates many levels of sub-organismal processes (e.g. molecular, cellular, organ system), an index such as Fulton's condition factor (Carlander 1969) may signify the overall condition and nutritional status of individual fish (Adams et al. 1992a)."

Weight determinations should be made on live or freshly killed fish. Unfortunately one limitation of the present study required cold shipping, freezing and thawing of samples prior to weighing. This undoubtedly increased the signal to noise ratio in our data.

Condition factor varies directly with nutritional status. Disease has been shown to be negatively correlated with condition. White suckers have been found to have enhanced condition factors in response to pulp mill effluents (Schmitt and Dethloff 2000). Decreased condition factors have been observed in white suckers in response to elevated concentrations of metals. "Nutrition, disease and contaminants are high inter-related in terms of their effects on fish condition." However, for white suckers, “[T]here is little evidence of regional differences in growth....Growth is very slow in some waters and rapid in others” (Carlander 1969: 481).

Greenfield and others (2001) observed that "....body condition changes rapidly in response to environmental perturbation (e.g., Mills et al. 2000)" and "is more indicative of current environmental constraints on growth than measures of past growth."

Condition factor also appears to vary seasonally, possibly as a response to changing food resources, metabolism, or gonadal status. "Condition indices can also vary from location to location within a species (Doyon et al. 1988; Fisher et al. 1996)." A decrease in weight due to a loss of energy reserves can be compensated for by increased body water (Schmitt and Dethloff 2000).

Schmitt and Dethloff (2000) caution that condition factor and organo-somatic indices must be interpreted carefully, as possibly confounding factors need to be identified in comparisons groups of fish for contaminant exposure effects. Comparison should only be within a species or between similar species.

Condition factor and organo-somatic indices can reflect adverse effects of chemical exposure that are not monitored routinely by water quality programs. Schmitt and Dethloff (2000:17) conclude:

> "The indices also integrate, at the organ system and organism level, the combined effects of multiple contaminants and the combined effects of contaminants and other stressors. A decrease in condition factor, the

[50] Organo-somatic indices include weight of organs, such as the liver.

HSI, or both is considered a reflection of depletion in energy reserves (Goede and Barton 1990); Barton et al. 1987) because these indices are positively related to total muscle and liver energy content (Lambert and Dutil 1997). A logical link then exists between this depletion of energy reserves and potential health problems for fish. An increase in both the condition factor or HSI can, however, also signal the deleterious effect of a stressor. Although the general interpretation is that a great weight relative to length indicates a healthier condition (for the individual organism), the presence of fewer, larger, and more robust individuals may signify an out-of-balance or abnormal condition at the population or community level (Wege and Anderson 1978; Hehtonen and Jokikokko 1995)."

Friedmann and others (2002) studied largemouth bass from one New Jersey lake and two reservoirs, with mean mercury levels of 0.3 ppm, 1.23 ppm, and 5.42 ppm. They measured a number of health and reproductive indicators including body weight, length, condition factor, and gonadosomatic index (GSI). Friedmann and others (2002) concluded, "..while elevated levels of mercury in fish potentially alter androgen profiles, they do not substantially decrease other indicators of general and reproductive health."

Greenfield and others (2001) note that other researchers have found condition to correlate negatively with Hg levels, possibly as an indication of growth efficiency. In a study of yellow perch from 43 northern Wisconsin lakes they found a negative correlation of -0.59 between body condition and mercury concentration. Only lake attributes of pH (r= -0.65) and alkalinity (r= -0.65) were more strongly negatively correlated with mercury. Greenfield and others (2001) also found age to not be correlated with mercury in yellow perch (r=0.02).

Greenfield and others (2001) concluded, that "Body condition of yellow perch, the strongest biological predictor of Hg levels in both the biological tree model and the combined multiple regression model, was also negatively corrrelated with pH." Therefore, they inferred "that body condition is related to Hg independently of pH."

However, Carlander's (1969; 1977; 1997) compilations of baseline weight-length equations and condition factors for many North American fishes support use of the condition factor in monitoring studies. Condition factor can be compared to empirical standards and is used in other national monitoring programs (Schmitt and Dethloff 2000). The condition factor can be used as another source of information for a weight-of-evidence determination of impairment or health.

5.2 Smallmouth Bass Weight, Length and Condition

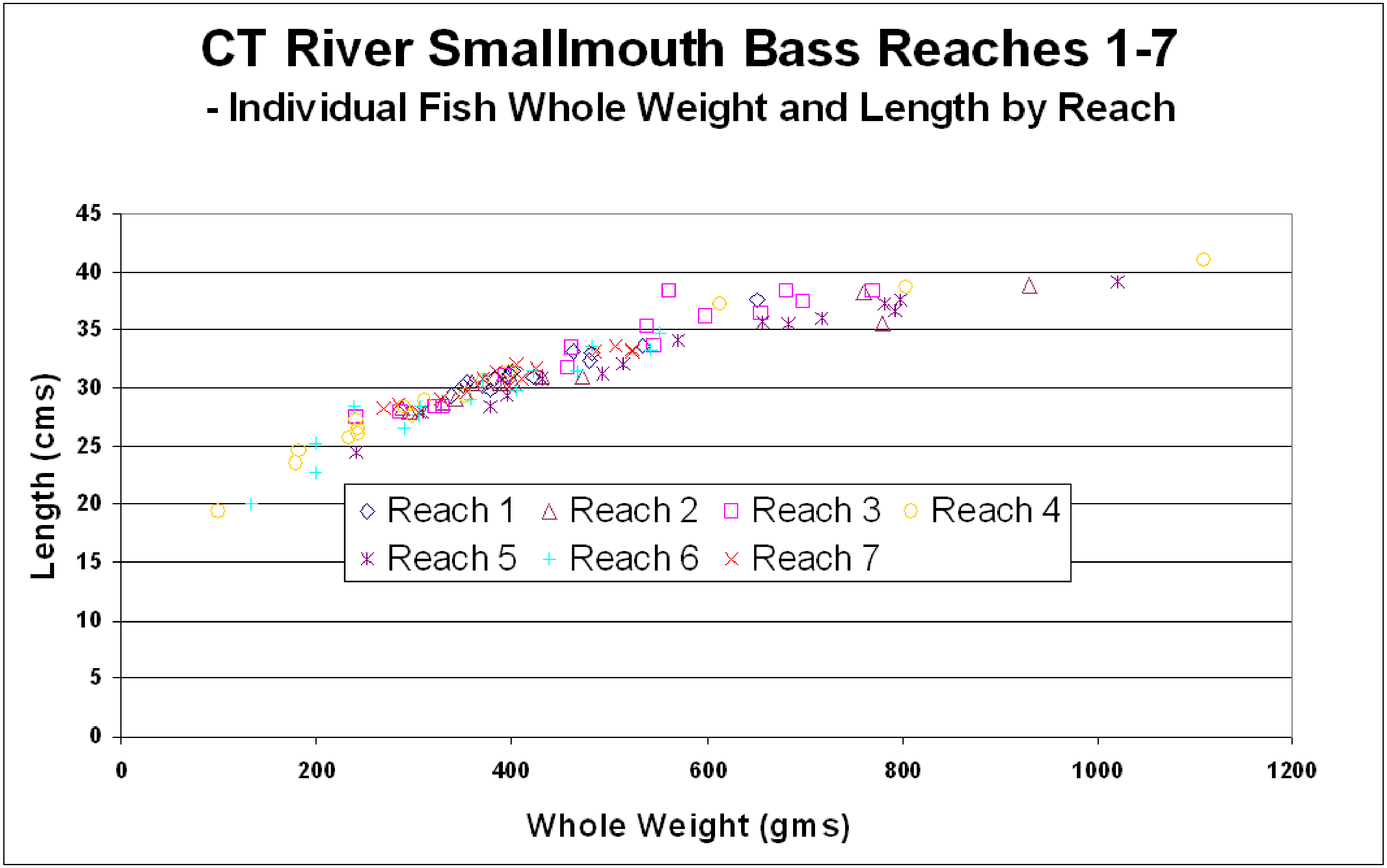

Figure 136. CT River Smallmouth Bass: Reaches 1-7 - Individual Fish Whole Weight and Length by Reach

Figure 137 shows both a non-parametric (Kruskal-Wallis) and parametric (ANOVA) statistically significant difference for individual smallmouth bass weight by Reach.

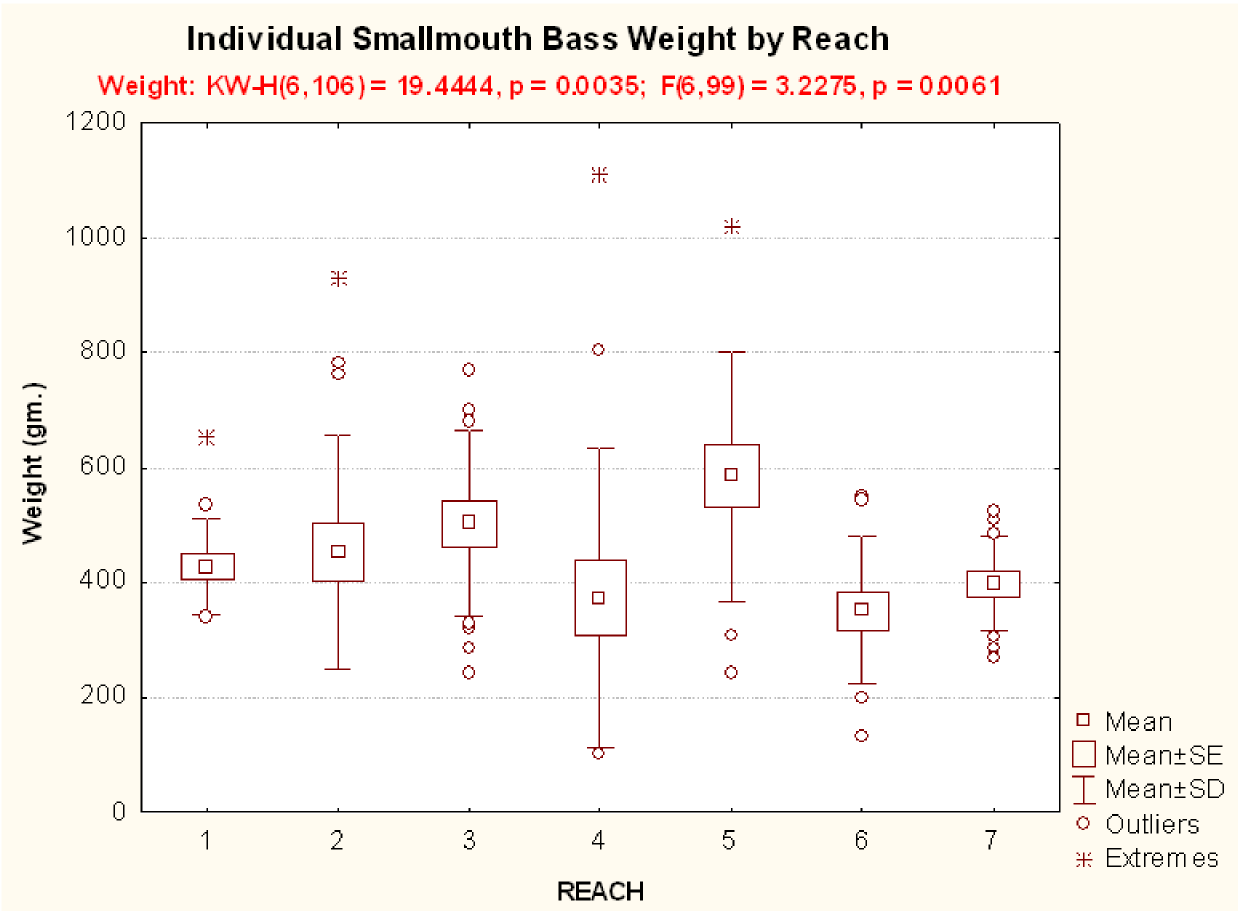

Figure 137. Individual Smallmouth Bass Weight by Reach

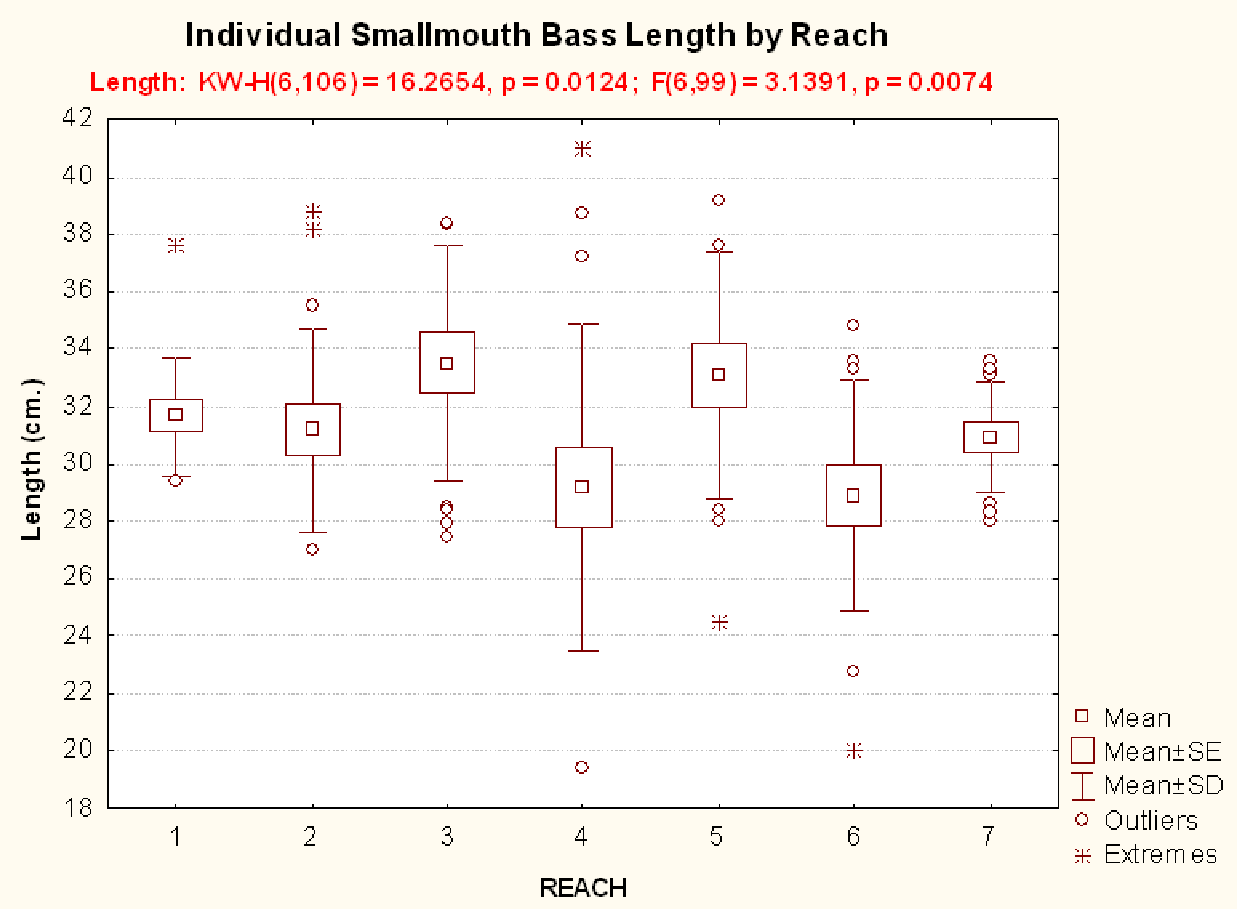

Figure 138. Individual Smallmouth Bass Length by Reach

Figure 138 shows both a non-parametric (Kruskal-Wallis) and parametric (ANOVA) statistically significant difference for individual smallmouth bass length by Reach.

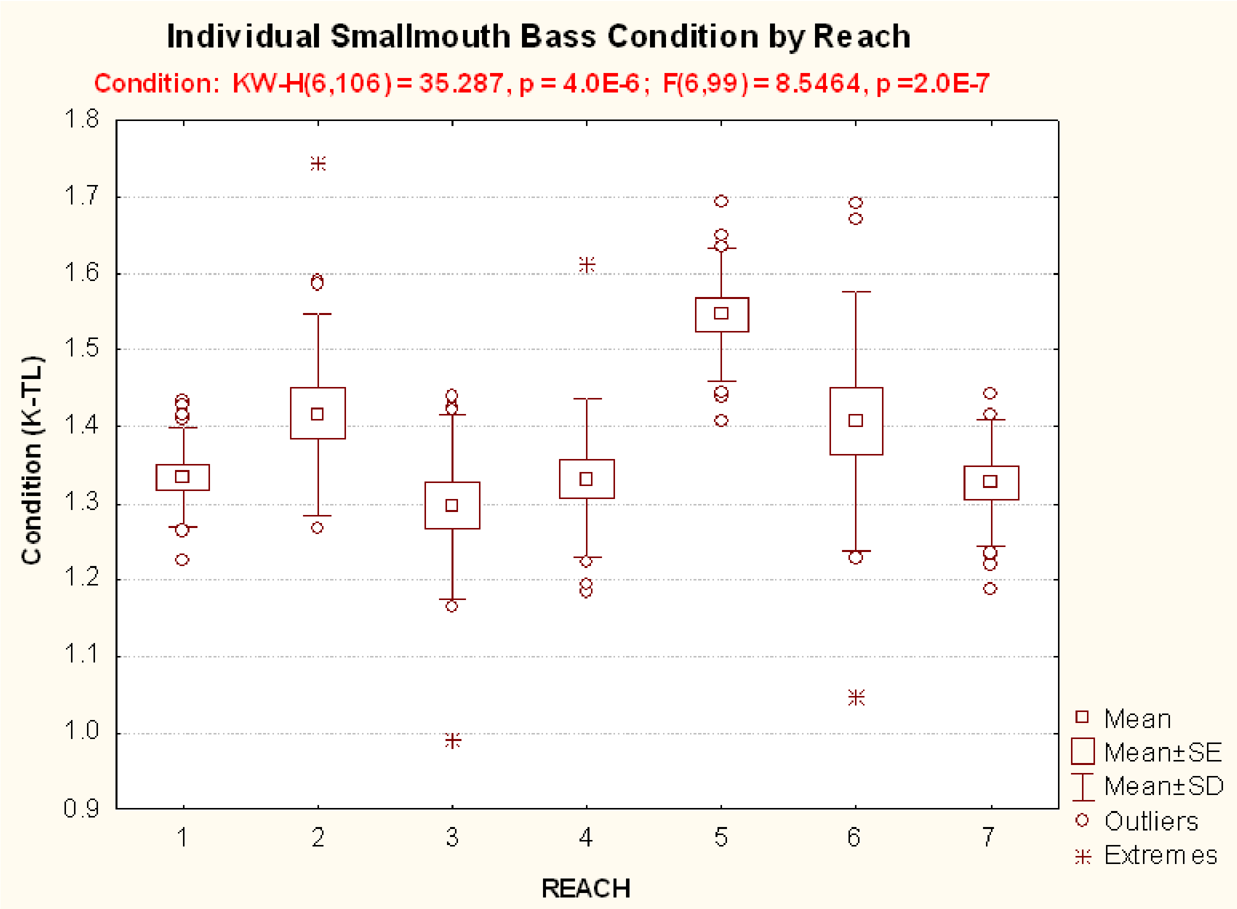

Figure 139. Individual Smallmouth Bass Condition by Reach

Figure 139 shows both a non-parametric (Kruskal-Wallis) and parametric (ANOVA) statistically significant difference for individual smallmouth bass condition (K-TL) by Reach.

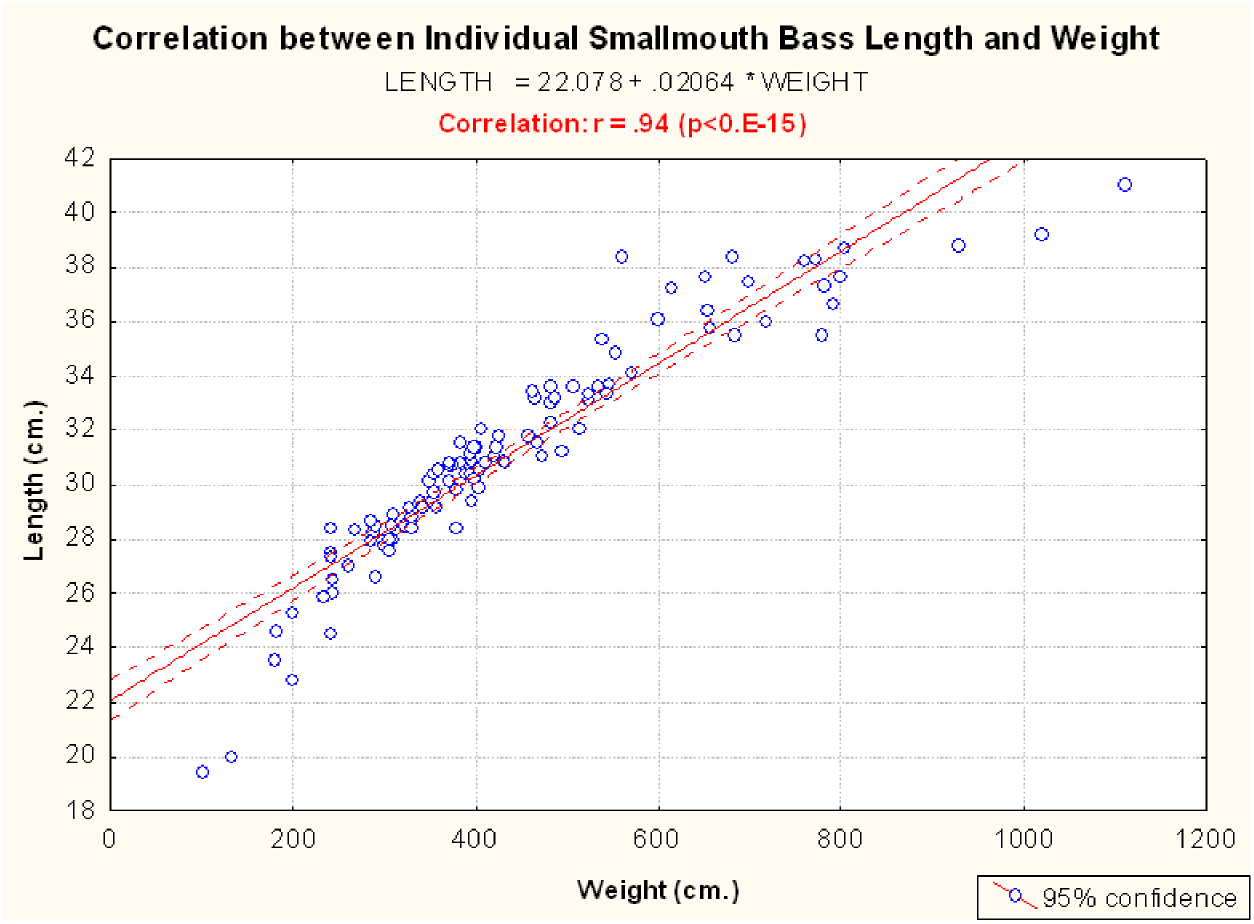

Figure 140. Correlation between Individual Smallmouth Bass Length and Weight

As expected, a highly statistically significant correlation (p<0.E-15) was observed between individual smallmouth bass weight and length sampled in Reaches 1-7 (Figure 140). Similar relationships were observed for yellow perch and white suckers.

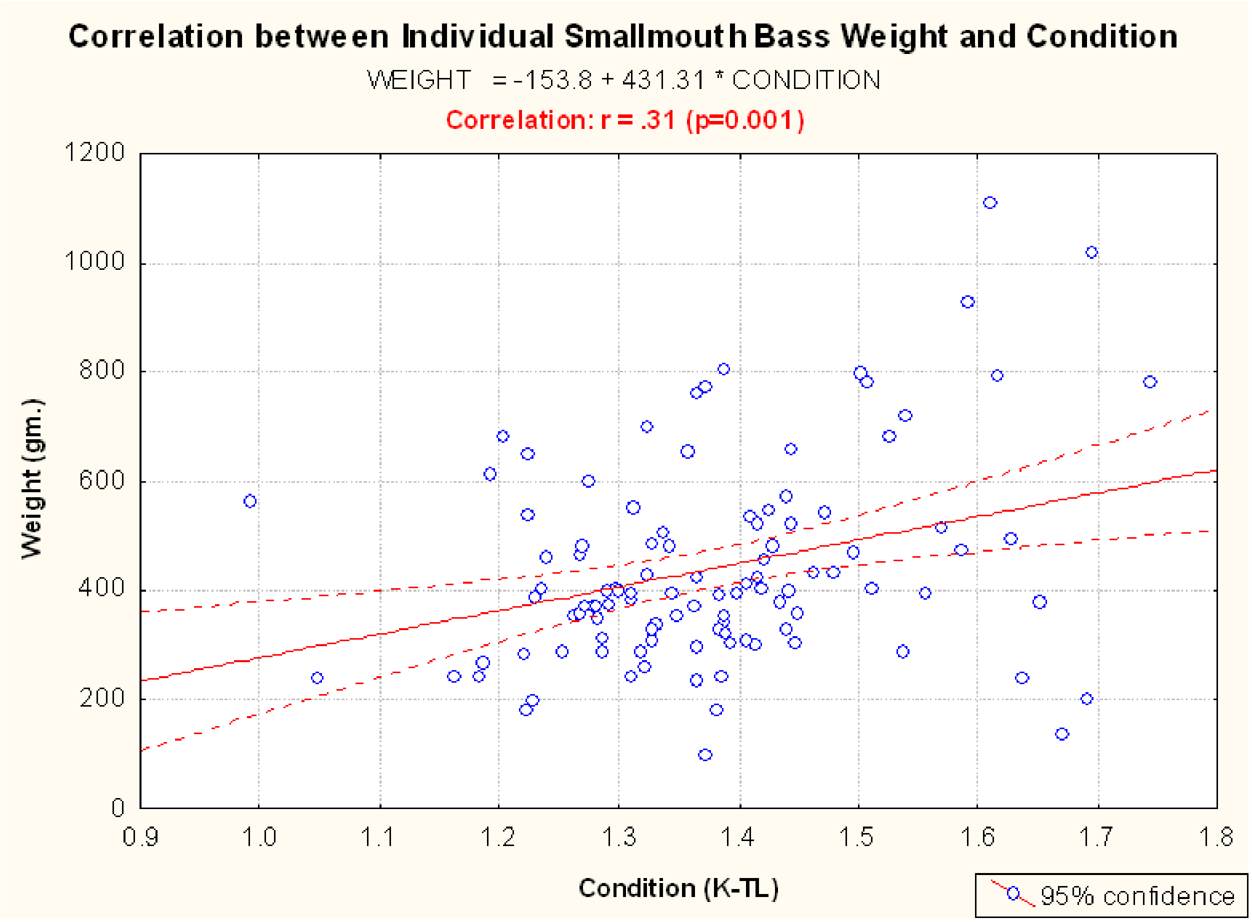

Figure 141. Correlation between Individual Smallmouth Bass Weight and Condition

A highly statistically significant correlation (p=0.001) was observed between individual smallmouth bass condition and whole weight (Figure 141) (i.e. heavier individual smallmouth bass had higher condition scores). No significant relationship was found between individual smallmouth bass length and condition.

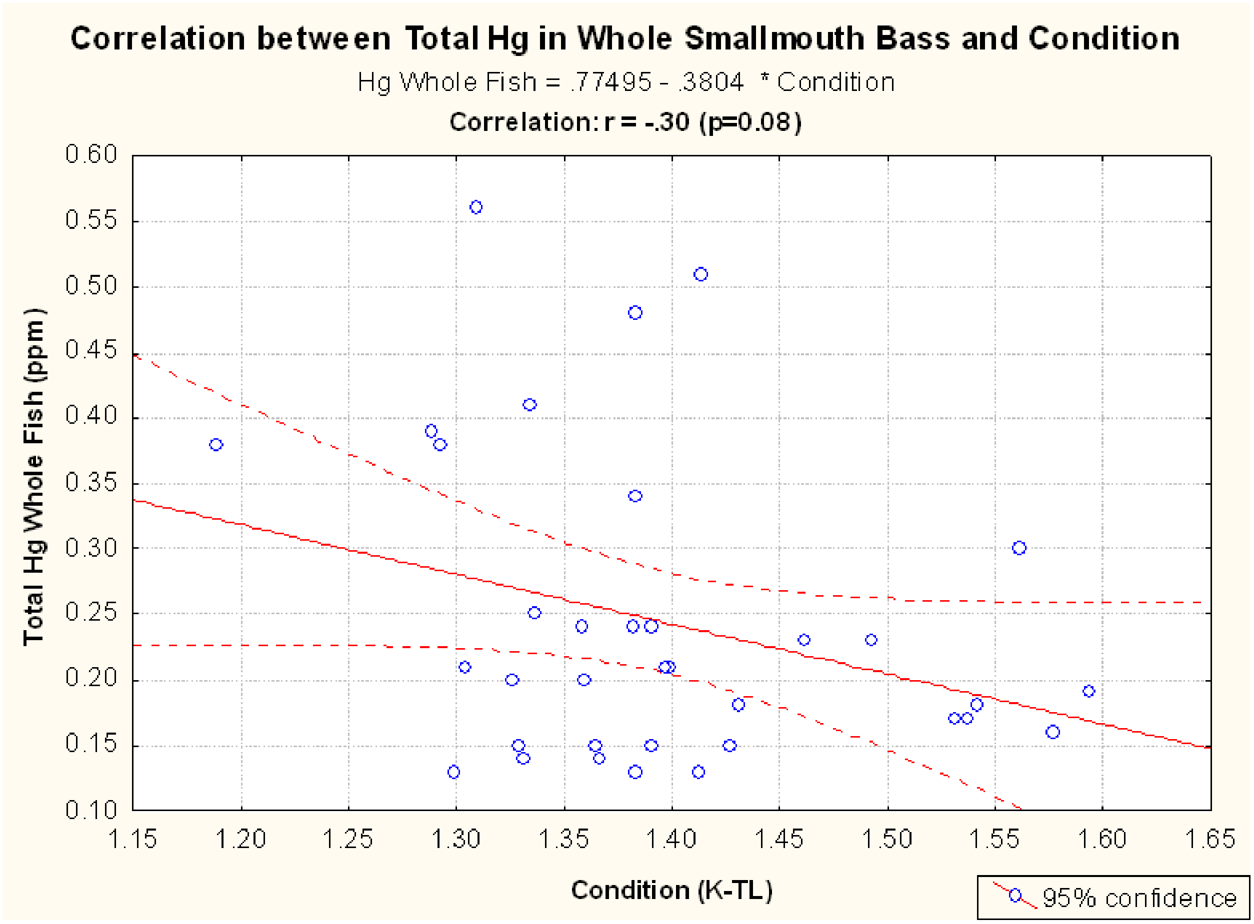

Figure 142. Correlation between Total Hg in Whole Smallmouth Bass and Condition

A non-significant negative correlation (p=0.08) was found between total mercury in whole smallmouth bass and condition (Figure 142).

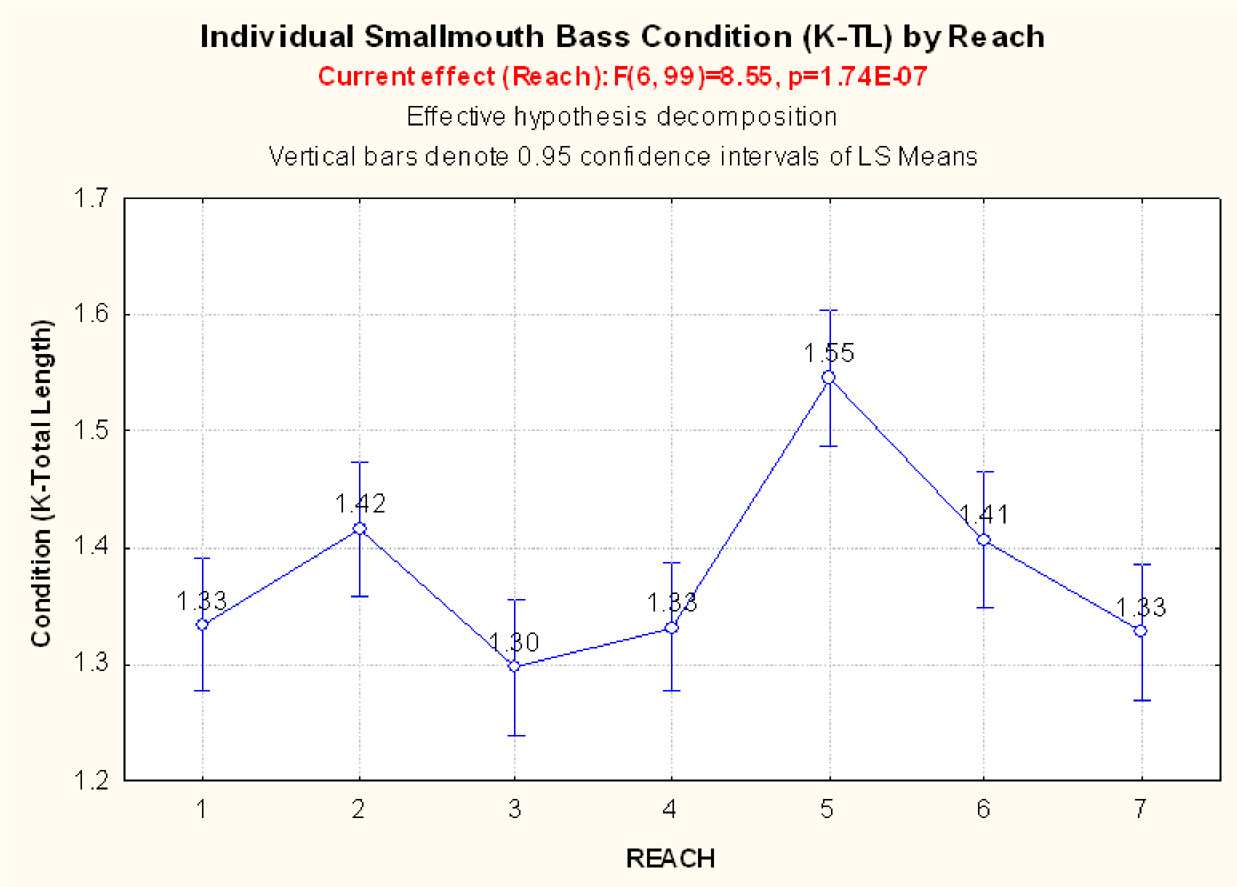

Figure 143. ANOVA of Individual Smallmouth Bass Condition (K-TL) by Reach

A one-way ANOVA found a highly significant effect for Reach (p=1.74E-07) in individual smallmouth bass condition (K-TL) (Figure 143). Table 55 summarizes the pair-wise comparison of inidividual smallmouth bass condition (K-TL) by Reach using Fisher's LSD Test. Reaches 1, 3, 4, and 7 were significantly lower than Reach 2. Reach 5 was significantly higher than all other Reaches. Reach 6 was significantly higher than Reach 3.

Table 55. Statistical Comparison of Individual Smallmouth Bass Condition (K-TL) by Reach (Fisher's LSD Post-Hoc Test of Least Square Means)

Least Square Means	1.33	1.42	1.30	1.33	1.55	1.41	1.33
REACH	**1 2**	**3**	**4**	**5**	**6**	**7**	
1		**0.05**	0.37	0.96	**1.48E-06**	0.08	0.87
2			**4.69E-03**	**0.04**	**2.30E-03**	0.81	**0.03**
3				0.39	**2.92E-08**	**0.01**	0.47
4					**8.66E-07**	0.07	0.90
5						**1.08E-03**	**7.24E-07**
6							0.06

5.3 Yellow Perch Weight, Length and Condition

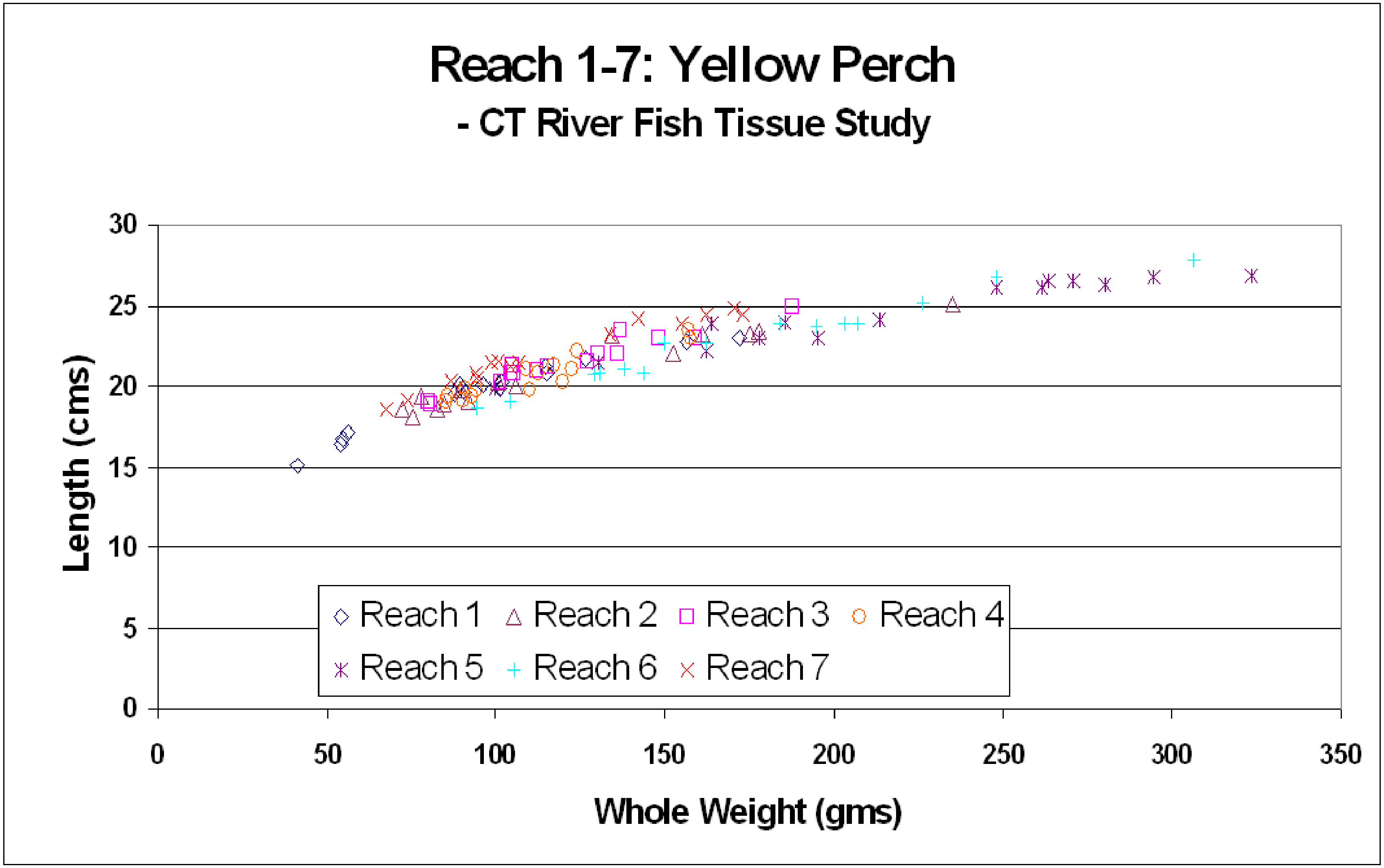

Figure 144. CT River Yellow Perch - Reaches 1-7: Individual Fish Whole Weight and Length by Reach

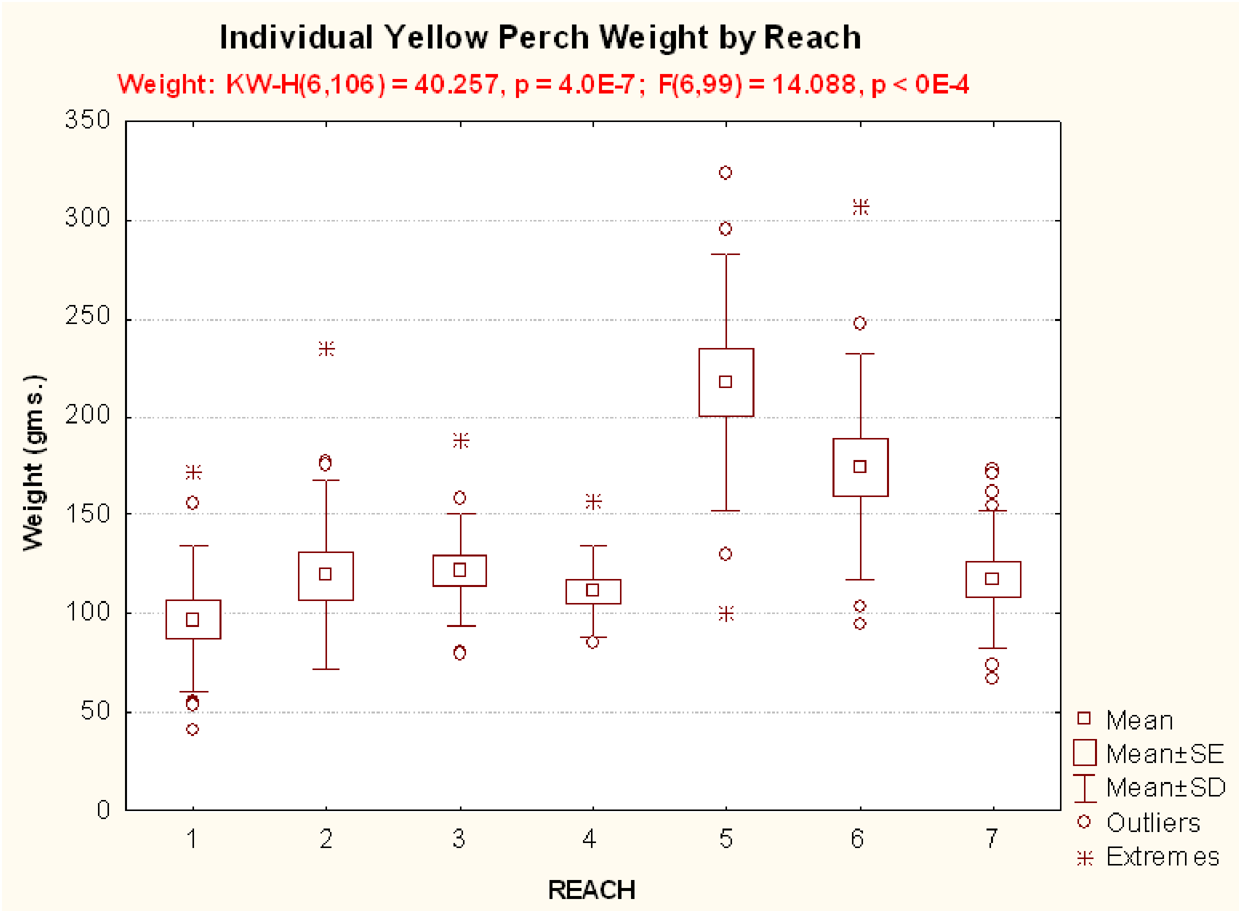

Figure 145. Individual Yellow Perch Weight by Reach

Figure 145 shows both a non-parametric (Kruskal-Wallis) and parametric (ANOVA) statistically significant difference for individual yellow perch weight by Reach.

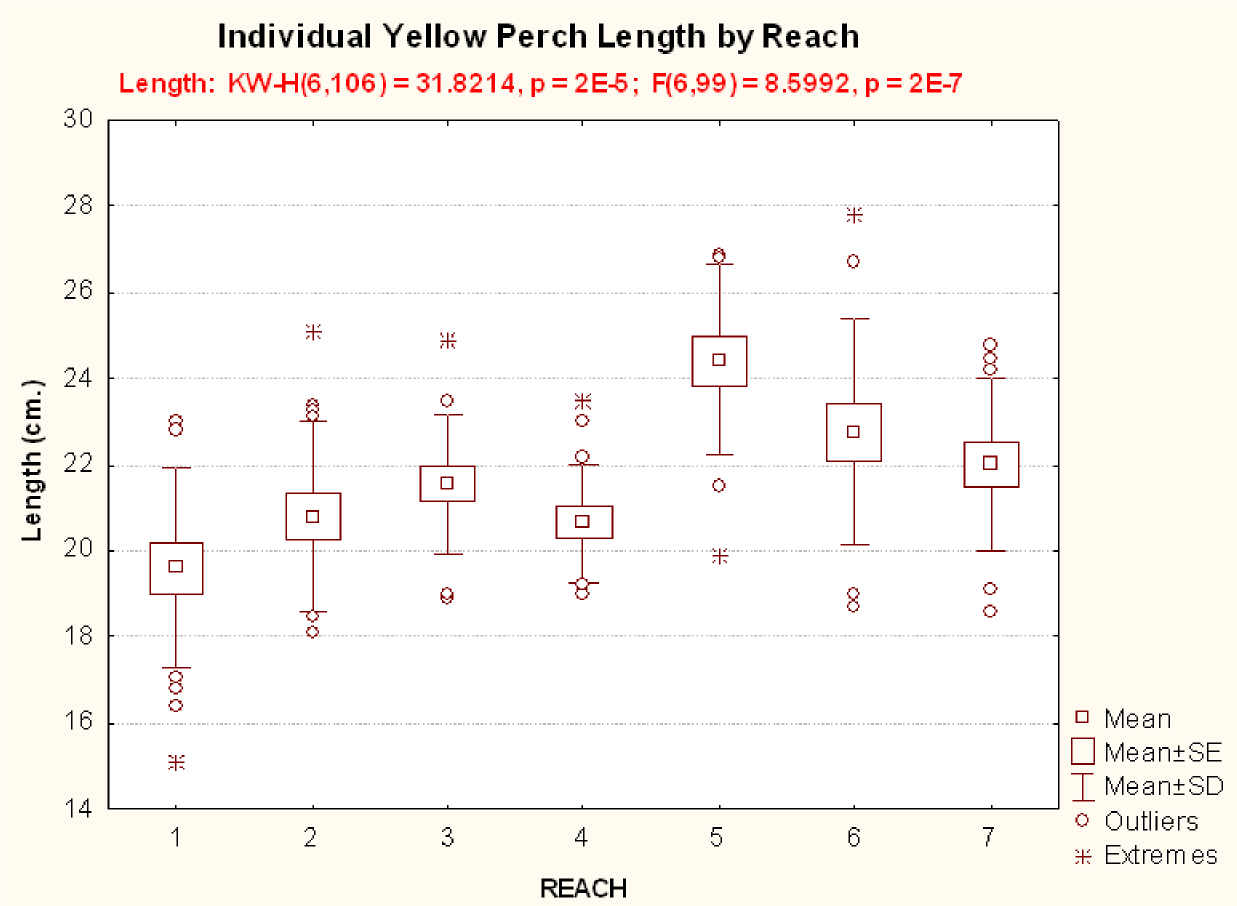

Figure 146. Individual Yellow Perch Length by Reach

Figure 146 shows both a non-parametric (Kruskal-Wallis) and parametric (ANOVA) statistically significant difference for individual yellow perch length by Reach.

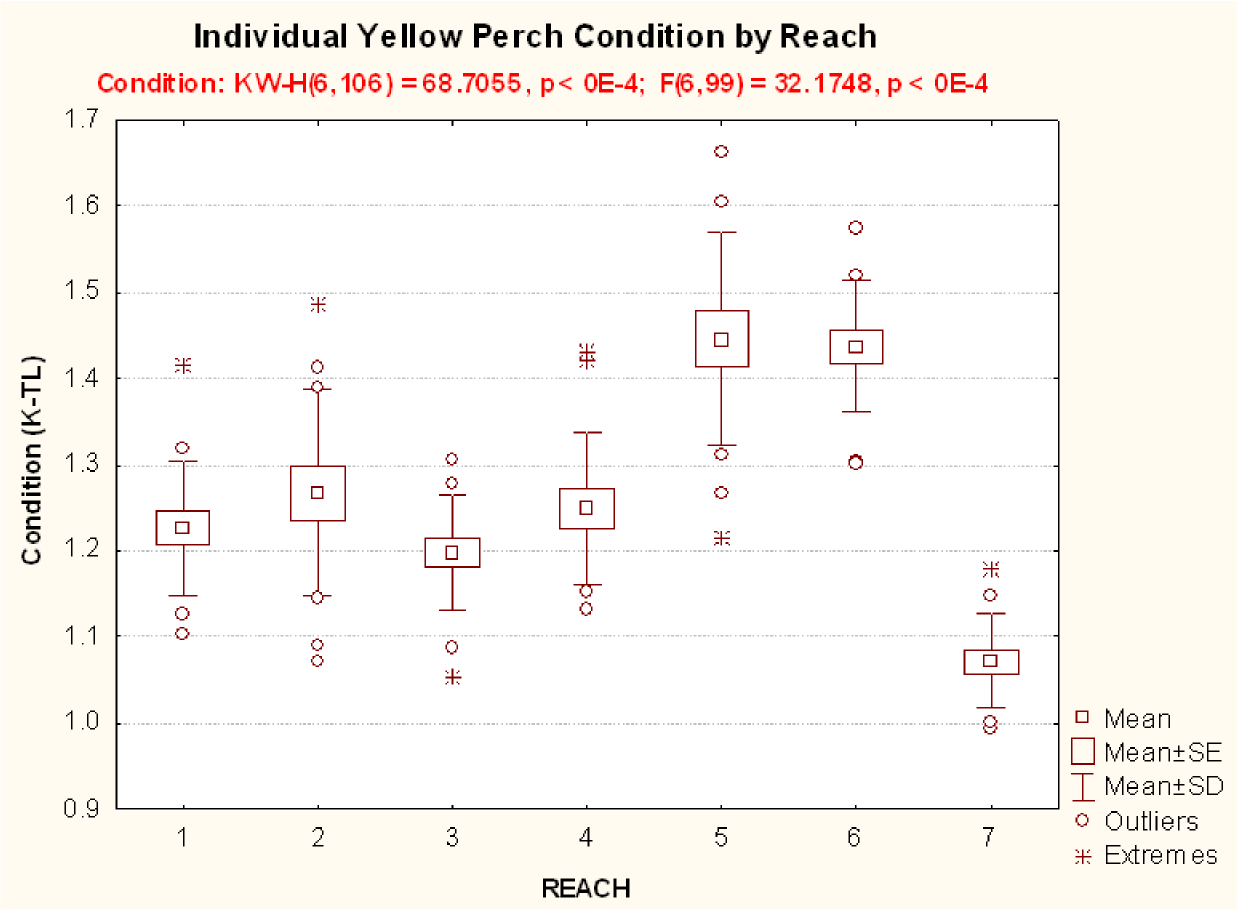

Figure 147. Individual Yellow Perch Condtion by Reach

Figure 147 shows both a non-parametric (Kruskal-Wallis) and parametric (ANOVA) statistically significant difference for individual yellow perch condition by Reach.

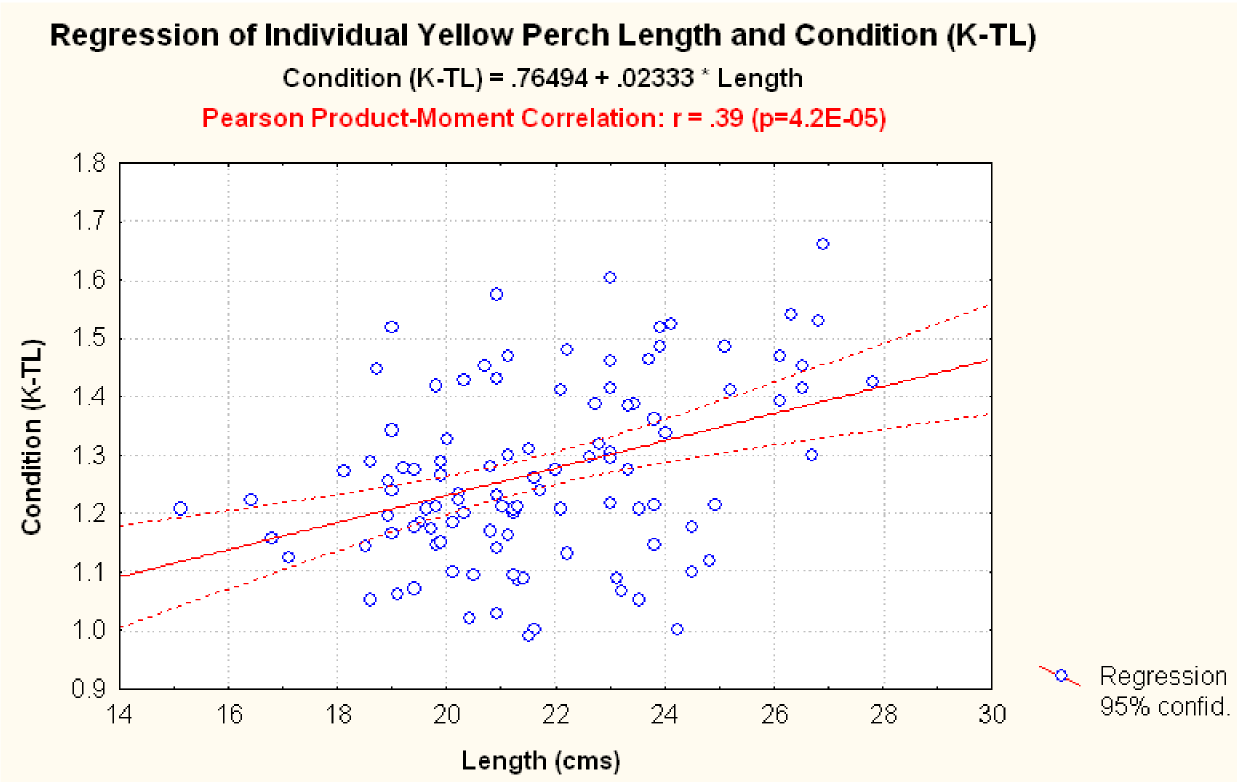

Figure 148. Regression of Individual Yellow Perch Length and Condition (K-TL)

Highly statistically significant positive correlations were observed between yellow perch length (p=4.2E-05; Figure 148), whole weight, composite total weight and condition (i.e. longer, heavier (individual and composite) yellow perch had higher condition scores).

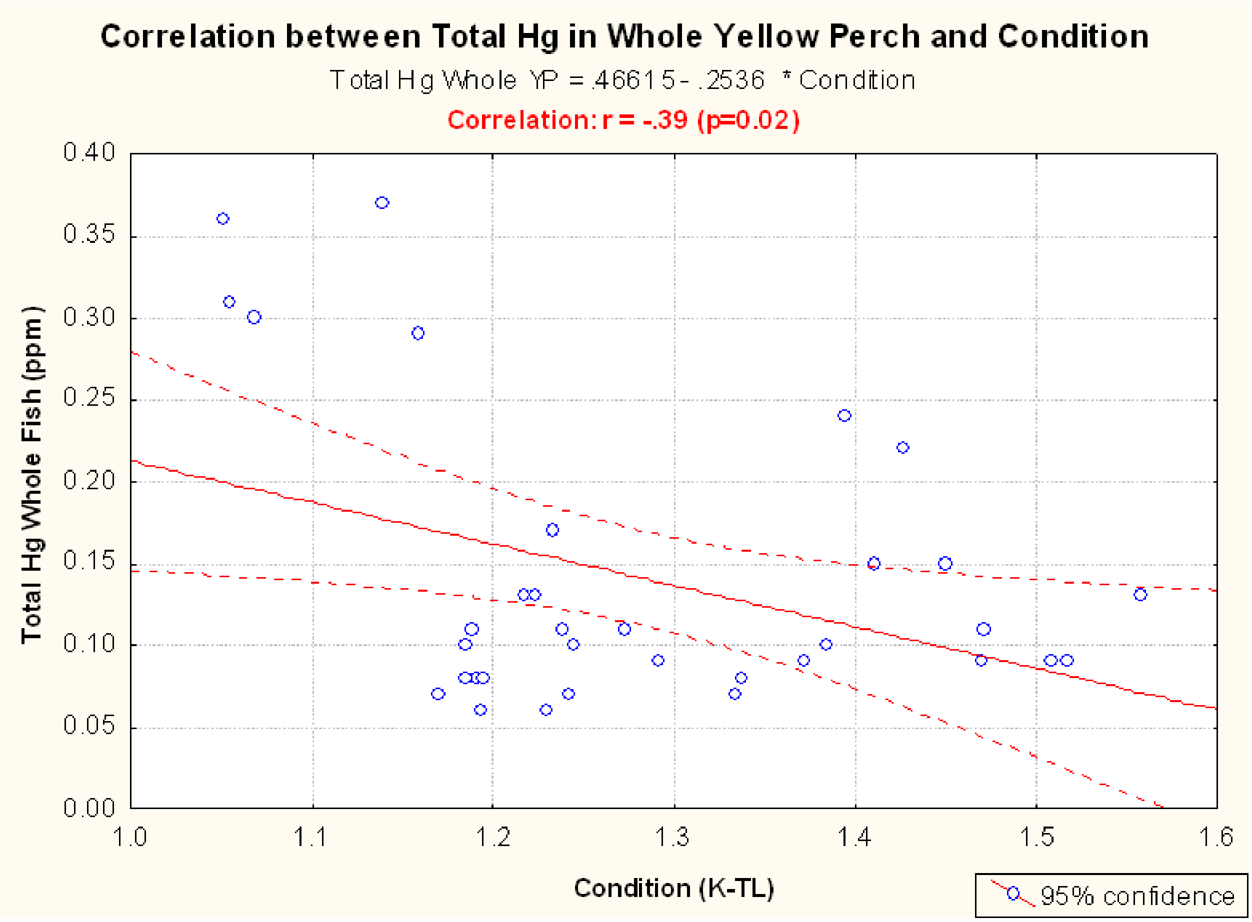

Figure 149. Correlation between Total Hg in Whole Yellow Perch and Condition

A statistically significant (p=0.02) negative correlation (r=-.39) was found between total mercury in whole yellow perch and condition (Figure 149). Those fish with higher mercury concentrations tended to have lower condition scores. It appears at lower mercury concentrations there is a much more variable effect on condition than at higher concentrations. A similar pattern was observed in smallmouth bass (Figure 140).

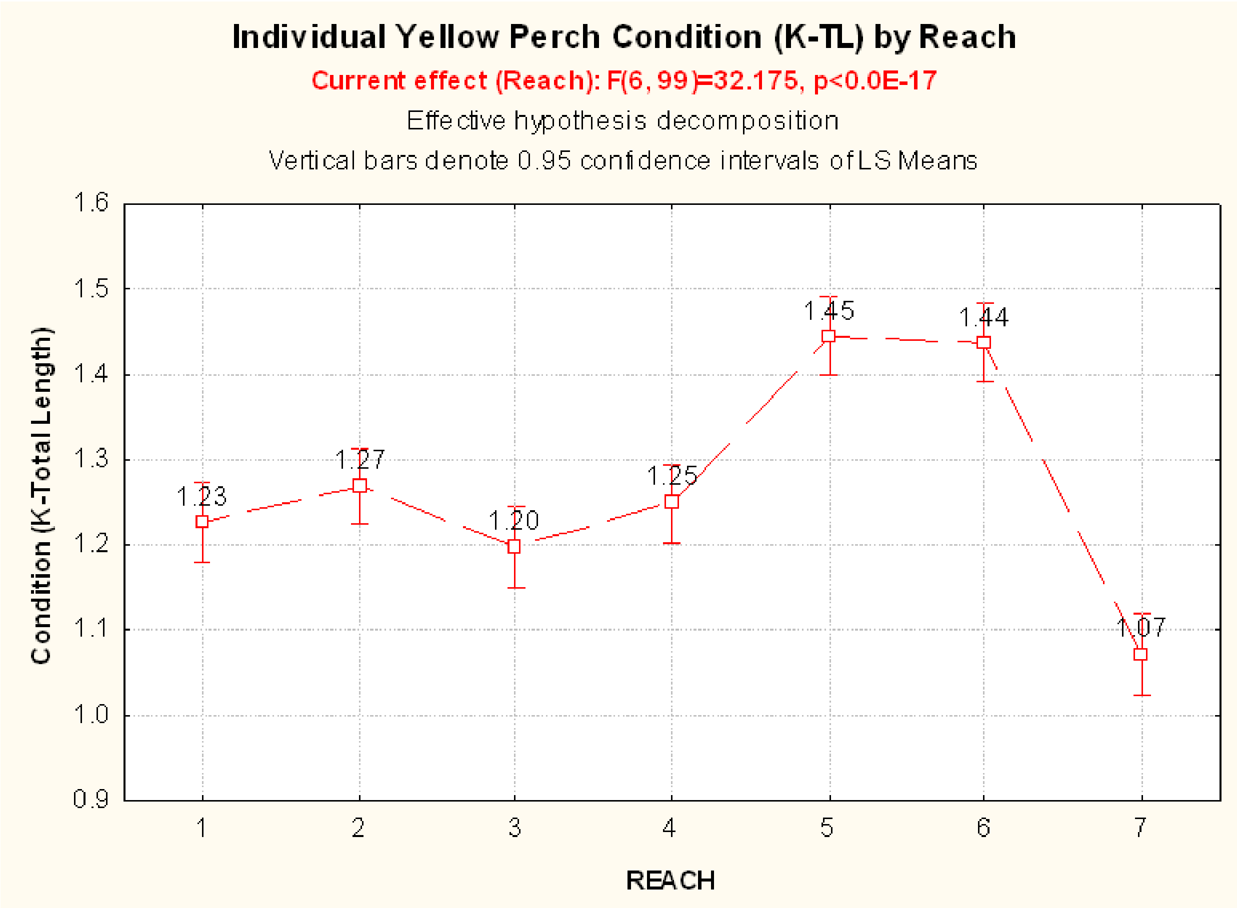

Figure 150. ANOVA of Individual Yellow Perch Condition (K-TL) by Reach

A one-way ANOVA found a highly significant effect for Reach ($p<0.0E-17$) in individual yellow perch condition (K-TL) (Figure 150). Table 56 summarizes the pair-wise comparison of individual yellow perch condition (K-TL) by Reach using Fisher's LSD Test. Reach 3 was significantly lower than Reaches 2, 5, 6, and higher than Reach 7. Reaches 5 and 6 were significantly higher than Reaches 1, 2, 3, and 4. Reach 7 was significantly lower than all other Reaches.

Table 56. Statistical Comparison of Individual Yellow Perch Condition (K-TL) by Reach (Fisher's LSD Post-Hoc Test of Least Square Means)

Least Square Means	1.23	1.27	1.20	1.25	1.45	1.44	1.07
REACH	**1**	**2**	**3**	**4**	**5**	**6**	**7**
1		0.21	0.39	0.49	**2.00E-09**	**5.80E-09**	**8.90E-06**
2			**0.03**	0.58	**3.63E-07**	**9.78E-07**	**3.00E-08**
3				0.12	**3.12E-11**	**9.42E-11**	**2.37E-04**
4					**4.73E-08**	**1.31E-07**	**5.10E-07**
5						0.82	**<0.0E-17**
6							**<0.0E-17**

5.4 White Sucker Weight, Length and Condition

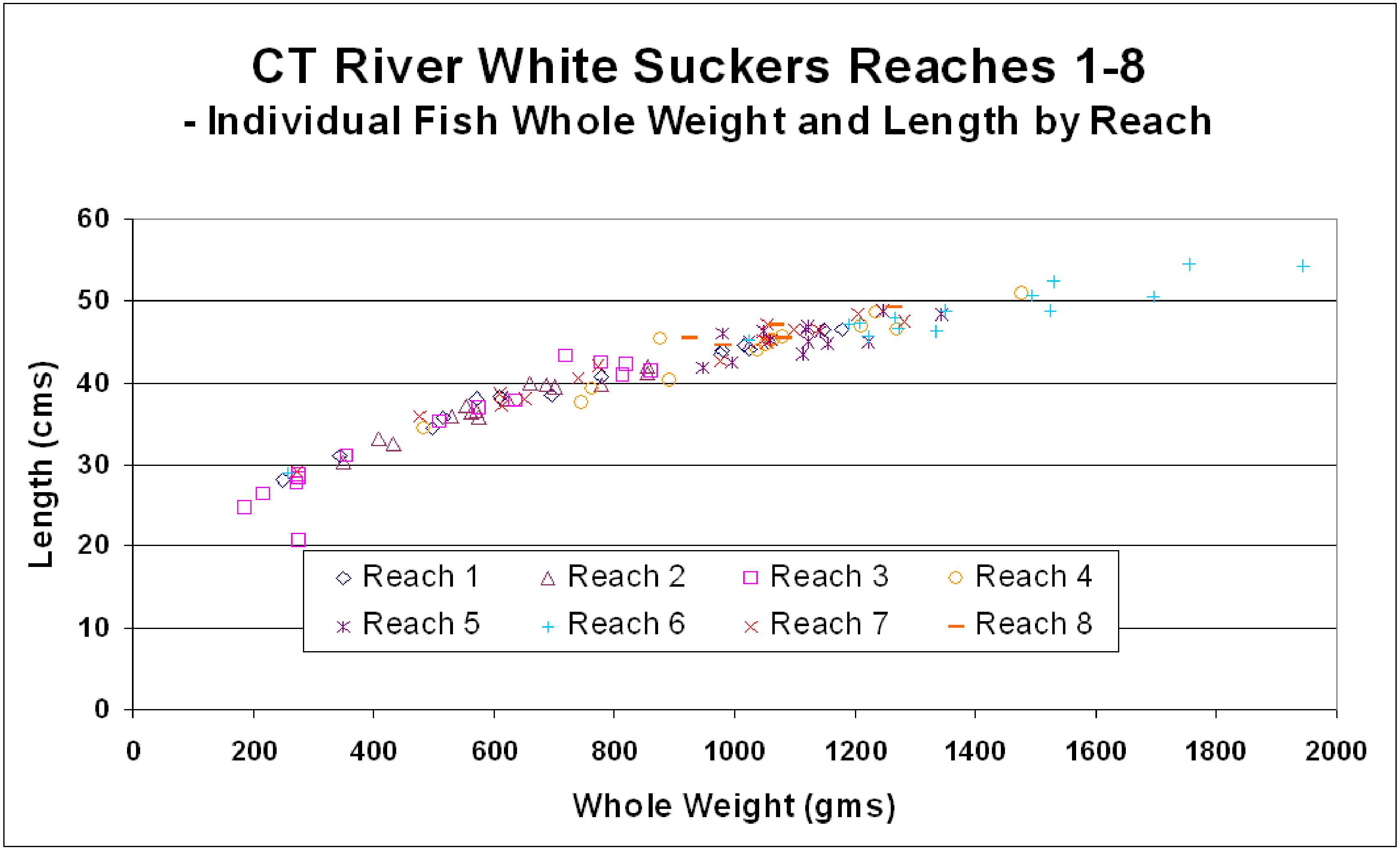

Figure 151. CT River White Suckers: Reaches 1-8 - Individual Fish Whole Weight and Length

Figure 152 shows both a non-parametric (Kruskal-Wallis) and parametric (ANOVA) statistically significant difference for individual white sucker weight by Reach.

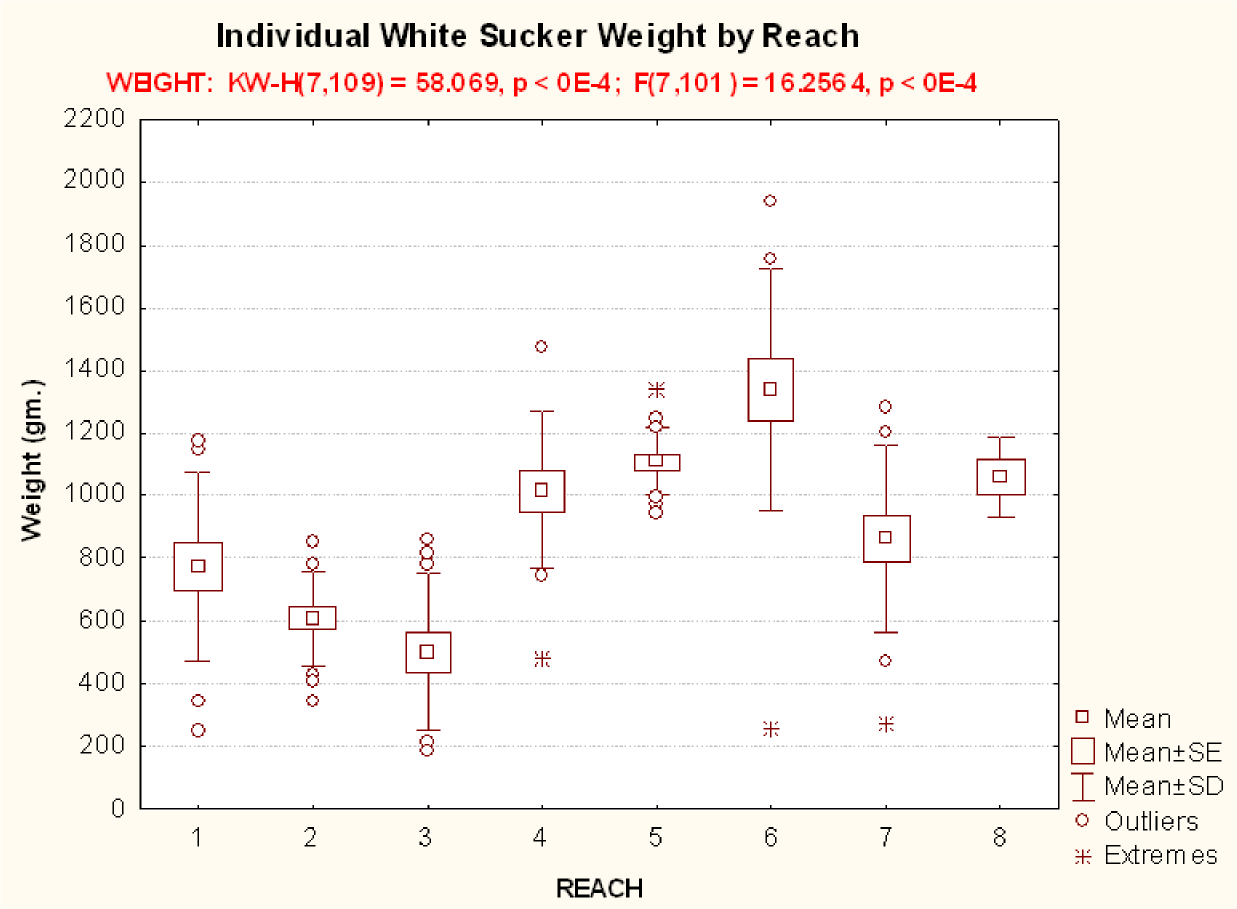

Figure 152. Individual White Sucker Weight by Reach

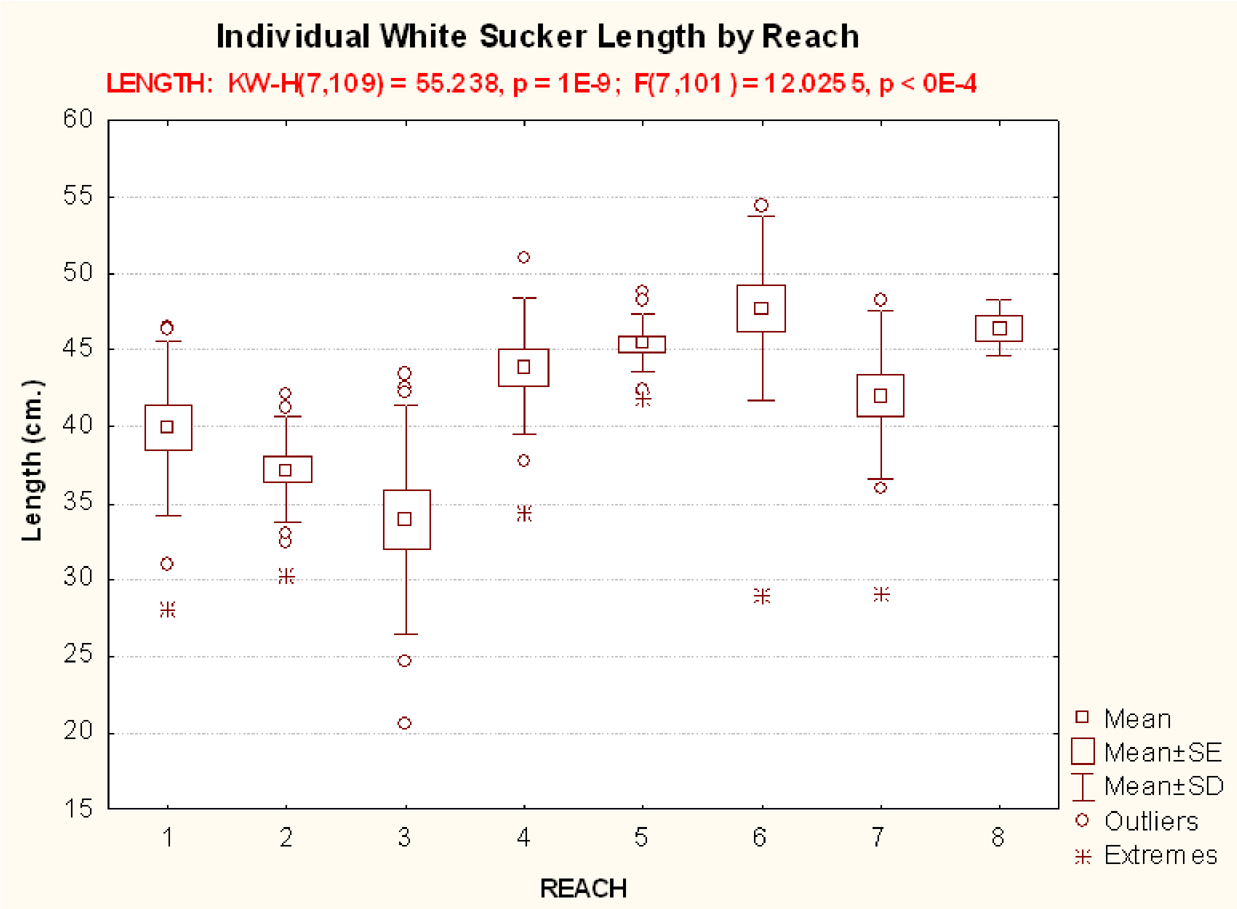

Figure 153. Individual White Sucker Length by Reach

Figure 153 shows both a non-parametric (Kruskal-Wallis) and parametric (ANOVA) statistically significant difference for individual white sucker length by Reach.

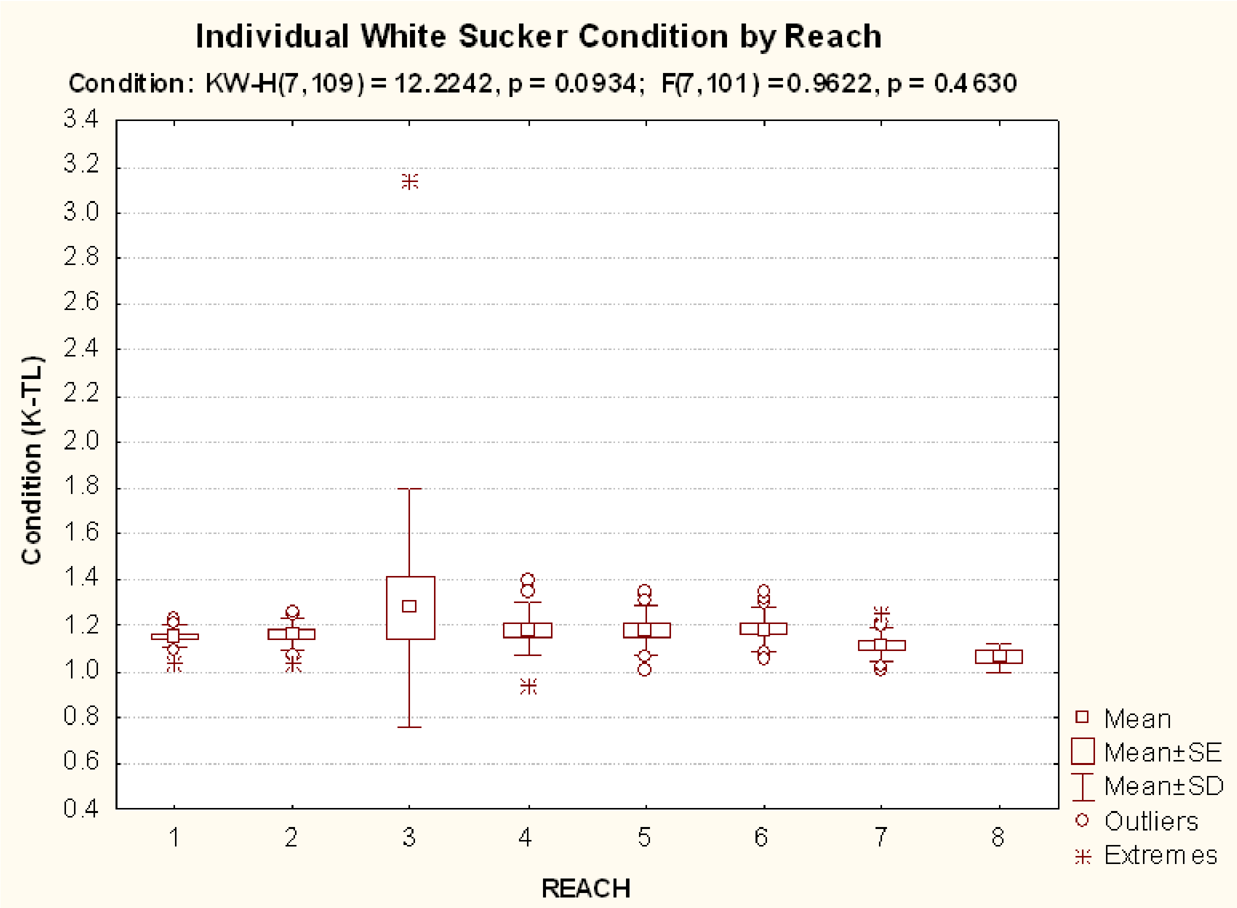

Figure 154. Individual White Sucker Condition by Reach

Figure 154 shows a non-significant difference for individual white sucker length by Reach.

Also, no significant relationship was observed between white sucker whole weight or length and condition.

Also, no significant relationship was found between total mercury in whole white suckers and condition.

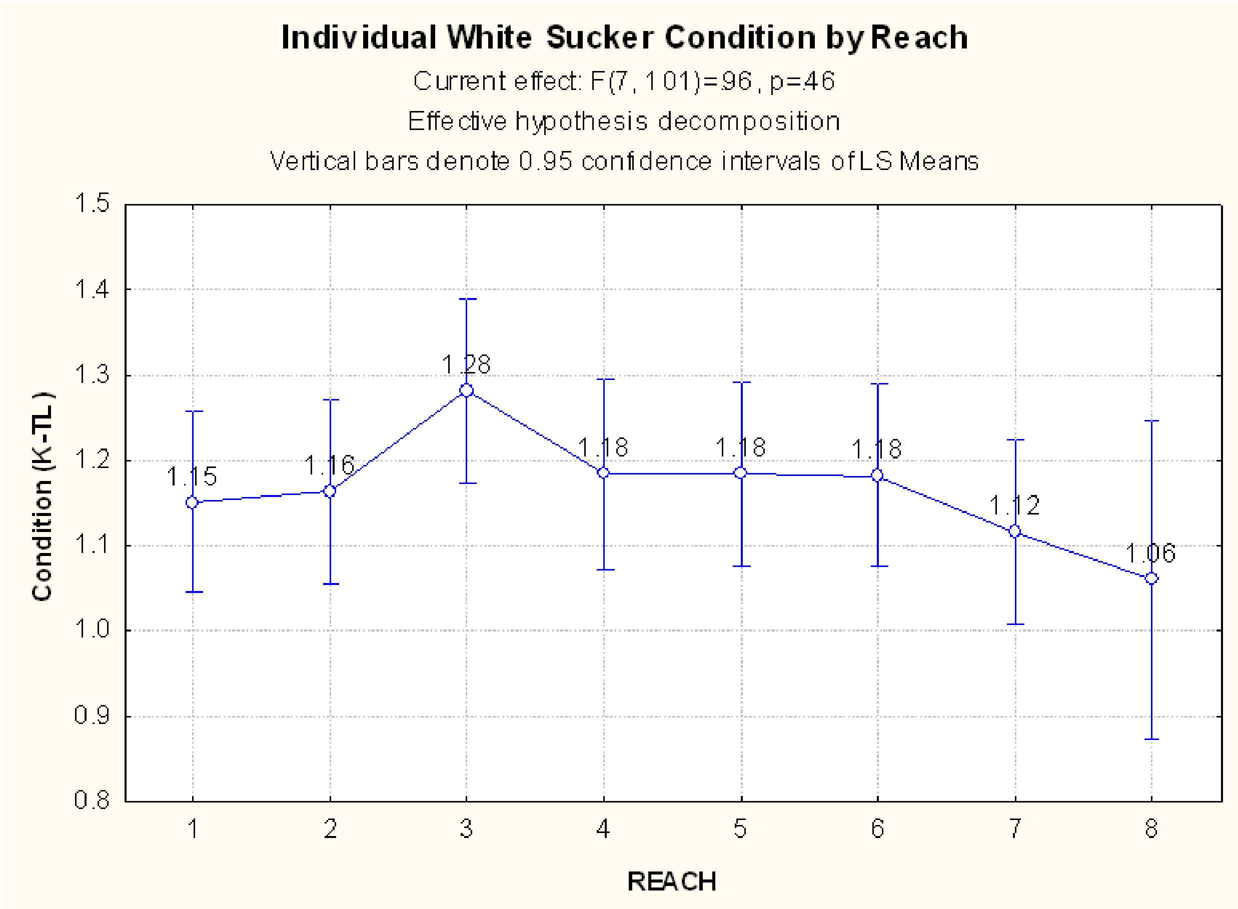

Figure 155. ANOVA of Individual White Sucker Condition by Reach

A one-way ANOVA found a non-significant effect for Reach (p=0.46) in individual white sucker condition (K-TL) (Figure 155). Table 57 summarizes the pair-wise comparison of individual white sucker condition (K-TL) by Reach using Fisher's LSD Test. Only Reach 3 was marginally significantly different than Reaches 7 and 8, which likely occurred by chance.

Table 57. Statistical Comparison of Individual White Sucker Condition (K-TL) by Reach (Fisher's LSD Post-Hoc Test of Least Square Means)

Least Square Means	**1.15**	**1.16**	**1.28**	**1.18**	**1.18**	**1.18**	**1.12**	**1.06**
REACH	**1 2**	**3**	**4**	**5**	**6**	**7**	**8**	
1		0.89	0.10	0.68	0.68	0.68	0.65	0.41
2			0.13	0.78	0.78	0.79	0.55	0.35
3				0.22	0.21	0.21	**0.03**	**0.05**
4					1.00	0.99	0.39	0.27
5						0.99	0.38	0.26
6							0.39	0.26
7								0.61

5.5 Conclusions

The condition factor (condition) (K-Total Length) was calculated for all individual smallmouth bass, yellow perch, and white suckers. K-TL (condition) has been used by fisheries biologists as a measure of health or "well-being" of fish. A number of factors including diet, disease, reproductive status, season and site-specific factors influence K-TL (condition). However, condition (K-TL) can be affected by chemical exposure. The condition factor (K-TL) can be used as another source of information for a weight-of-evidence determination of impairment or health. However, it is not meaningful to compare condition scores between species, thus no factorial ANOVA was conducted of species condition by Reach.

As expected weight and length were found to be highly statistically significantly correlated for smallmouth bass, yellow perch and white suckers. A highly statistically significant correlation ($p=0.001$) was observed between individual smallmouth bass condition and whole weight. No significant relationship was found between individual smallmouth bass length and condition. Highly statistically significant positive correlations were observed between yellow perch length, whole weight, composite total weight and condition. No significant relationship was observed between white sucker whole weight or length and condition.

A non-significant negative correlation ($r=-.30$; $p=0.08$) was found between total mercury in whole smallmouth bass and condition. A statistically significant negative correlation ($r=-.39$; $p=0.02$) was found between total mercury in whole yellow perch and condition. No significant relationship was found between total mercury in whole white suckers and condition.

A one-way ANOVA found a highly significant effect for Reach ($p=1.74E-07$) in individual smallmouth bass condition (K-TL). Reaches 1, 3, 4, and 7 were significantly lower than Reach 2. Reach 5 was significantly higher than all other Reaches. Reach 6 was significantly higher than Reaches 3.

A one-way ANOVA found a highly significant effect for Reach ($p<0.0E-17$) in individual yellow perch condition (K-TL). Reach 3 was significantly lower than Reaches 2, 5, 6, and higher than Reach 7. Reaches 5 and 6 were significantly higher than Reaches 1, 2, 3, and 4. Reach 7 was significantly lower than all other Reaches.

A one-way ANOVA found a non-significant effect for Reach ($p=0.46$) in individual white sucker condition (K-TL). Only Reach 3 was marginally significantly different than Reaches 7 and 8, likely a result of chance.

Clear inter-Reach differences were observed in smallmouth bass and yellow perch. Yellow perch appeared to have significantly lower condition with higher total mercury as observed by Greenfield and others (2001).